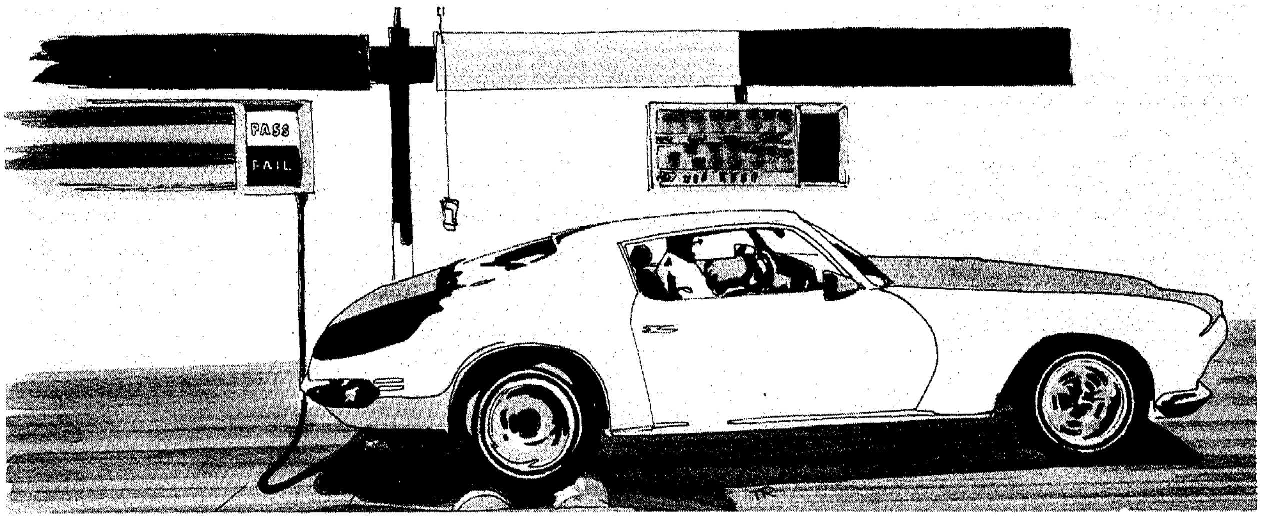
AUTOMOTIVE EXHAUST EMISSION STANDARDS



VOLUME I
EXECUTIVE SUMMARY

FINAL REPORT

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FOR

STATE OF CALIFORNIA
AIR RESOURCES BOARD

TRW / TRANSPORTATION & ENVIRONMENTAL OPERATIONS

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The results and conclusions are based on the latest, internally consistent emissions data base collected between 1970 - 1972. The extent to which these data are not representative of the vehicle population in the Los Angeles area, however, could have a significant impact on the resultant conclusions and recommendations. In particular, the lack of available data on 1973 - 1974 vehicles and on in-use fleet retrofitted vehicles may, to some extent, affect the results developed in this study.

PREFACE

This report discusses the establishment of loaded mode emission standards for the proposed California vehicle inspection and maintenance program. Development of these standards was undertaken in recognition of the role of exhaust emissions in the overall problem of air pollution for the South Coast Air Basin. A cost-effective approach was taken in designing emission standards for the vehicle population. Here, the interactions between modal emissions, mass emissions and vehicle characteristics were evaluated in arriving at a set of preferred emission criteria. Hopefully, these standards will play a key part in improving air quality for the region.

ACKNOWLEDGEMENTS

TRW would like to acknowledge the efforts extended by the California Air Resources Board in support of the project. The contributions of Messrs Gay Hass, Joe Calhoun and Ray Ingels were of particular significance.

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1.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations presented herein highlight the results from the emission standards program for the California Air Resources Board. A more definitive set of study observations and results can be found in Volume II (Technical Analysis).

- An initial vehicle rejection rate of approximately 30 percent yields the most cost-effective results for a loaded mode inspection and maintenance program.

- The average emission reductions (CVS measurements) for a 30 percent rejection rate are 9.0%, 7.9% and -0.9% for HC, CO and NOx, respectively. These performance estimates do not include the impact of engine deterioration. The reduction potential for 1971-1974 vehicles will tend to increase with use and consequently these overall estimates of emission reduction are conservative.

- Nearly 15 percent of those vehicles which undergo maintenance for failing the initial inspection will fail the subsequent re-test (i.e., approximately 5 percent of the total population).

- The emission standards have been designed with an emphasis on HC reduction. This is in keeping with the reactive hydrocarbon-photochemical nature of the air pollution problem for the South Coast Air Basin.

- The influence of engine deterioration, owner tampering and unreliable repair have not been considered directly in establishing the key mode standards. The existence of these factors could have a substantial effect on resultant emission reductions for a given rejection level. In general, more severe standards (i.e., failure of a larger percentage of the population) will be required to achieve a comparable emission reduction level in the presence of these elements.

- No practical procedures exist at the present time for establishing NOx emission standards for pre-1966 (non-retrofited vehicles) and 1966-1970 vehicles. This situation can be attributed to the inverse relationship between CO control and NOx control and the lack of effective emission modal diagnostic signatures.

- Classifications are required to adequately describe the vehicle population in consistent terms. Applying a uniform set of standards to the entire population will lead to ineffective and socially regressive results.

- The most descriptive vehicle population classification scheme was found to include age and engine size (i.e., number of cylinders). In particular, three age classifications (pre-1966, 1966 - 1970 and 1971 - 1974) and three engine size groups (4, 6 and 8 cylinders) appear most descriptive. Using this engine classification scheme helps maintain a high level of program efficiency because of the relative ease in identifying the number of cylinders per vehicle.

- While different combinations of engine displacement groupings were found most descriptive for each age category, for operational consistency a uniform set was established. This scheme separates the vehicle population into 4 cylinder and 6 or 8 cylinder classes for the three age groups. The impact of their simplification on emission reduction effectiveness was found to be substantially less than the potential effects of engine deterioration, owner tampering or unreliable repair. Furthermore, it will have a positive influence on reducing operational errors at the inspection station.

- The analysis yielded loaded mode emission standards which reject approximately equal numbers among the various classification elements. These results tend to minimize the social regressiveness of the program while at the same time providing cost-effective emission reduction performance.

- Different levels of vehicular rejection may occur locally as a result of implementing the standards on a region wide basis. That is, the spatial distribution of the vehicle population is not uniform and consequently different rejection rates can be expected as a function of station location.

- Thirty six different standards have been established for various segments of the vehicle population. This includes three age groups, two engine displacement types, two emission and three measurement modes (3x2x2x3 = 36). In addition, separate standards have been developed at idle for air pump equipped vehicles and non-air pump equipped vehicles. A NOx screening standard on 1971 - 1974 vehicles also has been recommended.

- The developed loaded mode emission standards were designed to identify those vehicles where maximum emission reductions (as measured in CVS units) could be achieved for a given rejection level. The process considered the potential interactions between modes, emissions and vehicle characteristics in arriving at the preferred standards. This approach insures the establishment of the most cost-effective set of emission standards.

- The data base used in this study contained vehicles that underwent comprehensive engine repair. Those vehicles failing a particular emission mode (e.g., idle) had all detected malfunctions repaired as opposed to repair of only those items causing failure.

- Modal emission rejection levels will tend to decrease over time as more vehicles receive corrective maintenance. A periodic updating of the emission standards may be necessary to achieve a consistent level of emission reduction from the vehicle population.

- An interim set of loaded mode emission standards should be established during the initial phase of the basin wide demonstration program. This will permit adequate time to check out and update basic procedural and system operations.

- Emission data should be developed to better characterize NOx emissions from vehicles with failed NOx control systems. Test data should also be collected for 1973 - 1974 vehicles with and without air pumps.

- An ongoing emission measurement program is required to obtain the data necessary to establish emission standards for post-1974 vehicles. The surveillance system should include both CVS and loaded mode measurements with particular emphasis on NOx emissions and diagnostic data.

- Because of the multiplicity of emission control systems for post-1970 vehicles, a functional or diagnostic inspection approach may be, in the limit, more cost-effective than an emission inspection test.

- The developed standards may not be applicable to those vehicles which have been retrofitted with emission control devices (pre-1966,VSAD, 1966 - 1970, VSAD and EGR). Separate standards were not developed for these classes of vehicles because of the lack of empirical data. It is recommended that test data be collected on these vehicles as an integral part of the inspection program.

2.0 INTRODUCTION

California Senate Bill 479 requires the Department of Consumer Affairs, in concert with the Highway Patrol and the Air Resources Board (ARB), to design and adopt a program for the mandatory inspection and maintenance of all motor vehicles operating within the six county South Coast Air Basin. Under this act, it is the responsibility of the ARB to set the emission standards for use in the inspection program. This study, requested by the legislature, is designed to establish a comprehensive set of key mode emission standards in support of the overall inspection program.

A program of vehicular inspection and maintenance is, in principle, a simple and direct near-term approach for controlling exhaust emissions from the vast majority of the automotive population. This control program can be accomplished by employing any one of a number of basic alternatives, e.g., idle, loaded, hybrid. In general, it requires a periodic inspection of each vehicle in the population to determine whether or not it conforms to existing emission standards or engine specifications. Those vehicles failing the inspection procedure are required to undergo subsequent maintenance to return their operations to acceptable levels. All cars, both old and new, feel the direct impact of this control approach. A vehicular inspection program represents a flexible strategy relative to the problem of emission control for not only is it a separate alternative in itself, but it can be used in conjunction with the introduction of advanced emission control systems.

The use of emission tests, such as a loaded mode, to determine the extent of engine maladjustments and malfunctions is desirable from two prespectives. First, the approach tends to have substantially lower costs than the so-called functional tests; and, second it provides some indication of vehicular emission levels. Unfortunately, an emission inspection is confronted by both errors of omission and commission which, if not properly designed for, can yield ineffective results. The current study has been designed to consider both classes of errors in establishing effective emission standards.

One of the basic elements and major impact variables influencing program design is the inspection criteria. For a loaded mode oriented inspection, a number of unique standards must be established for the various combinations of modes, emission species, and vehicle types, e.g., idle HC for pre-1966 four cylinder vehicles. These inspection standards, in effect, will specify the level of vehicle rejection which in turn will determine the resultant emission reductions and associated costs. Typically, higher rejection rates lead to greater emission reductions at higher program costs while lower rates yield smaller reductions at somewhat reduced costs. The establishment of "optional" key mode emission standards requires an assessment of both reduction effectiveness and costs.

3.0 TECHNICAL ANALYSIS OF EMISSION STANDARDS

3.1 Overview

This section describes the basic methodological approach used in establishing the loaded mode standards. Although the proposed California program may include procedures other than loaded mode (i.e., direct functional testing), they were not evaluated during the course of this study. The primary objective of this analysis was to develop an optimal set of loaded mode standards for various segments of the vehicle population. Specific diagnostic analyses are presented, however, in the case of NOx and post-1974 emission control systems.

The complex nature of defining effective loaded mode standards required the application of a comprehensive data management and analysis approach. Basically, the analysis consisted of evaluating emission signature measurements taken from over 3,000 vehicles operating in the Los Angeles area. The data base was developed from previously conducted experiments on a sample representative of the current vehicle fleet. This approach permitted an indepth examination of relevant key mode, CVS and engine diagnostic data from both inspected and maintained vehicles. Figure 3-1 presents an overview schematic of the methodological approach used in the study.

3.2 Study Data Base

Several sets of vehicular emissions and engine diagnostics were collected and evaluated for potential use in this study. The reason for utilizing a large data base stems from the need to partition the vehicle fleet into a number of sub-populations which can be characterized with sufficient statistical accuracy. Table 3-1 summarizes the

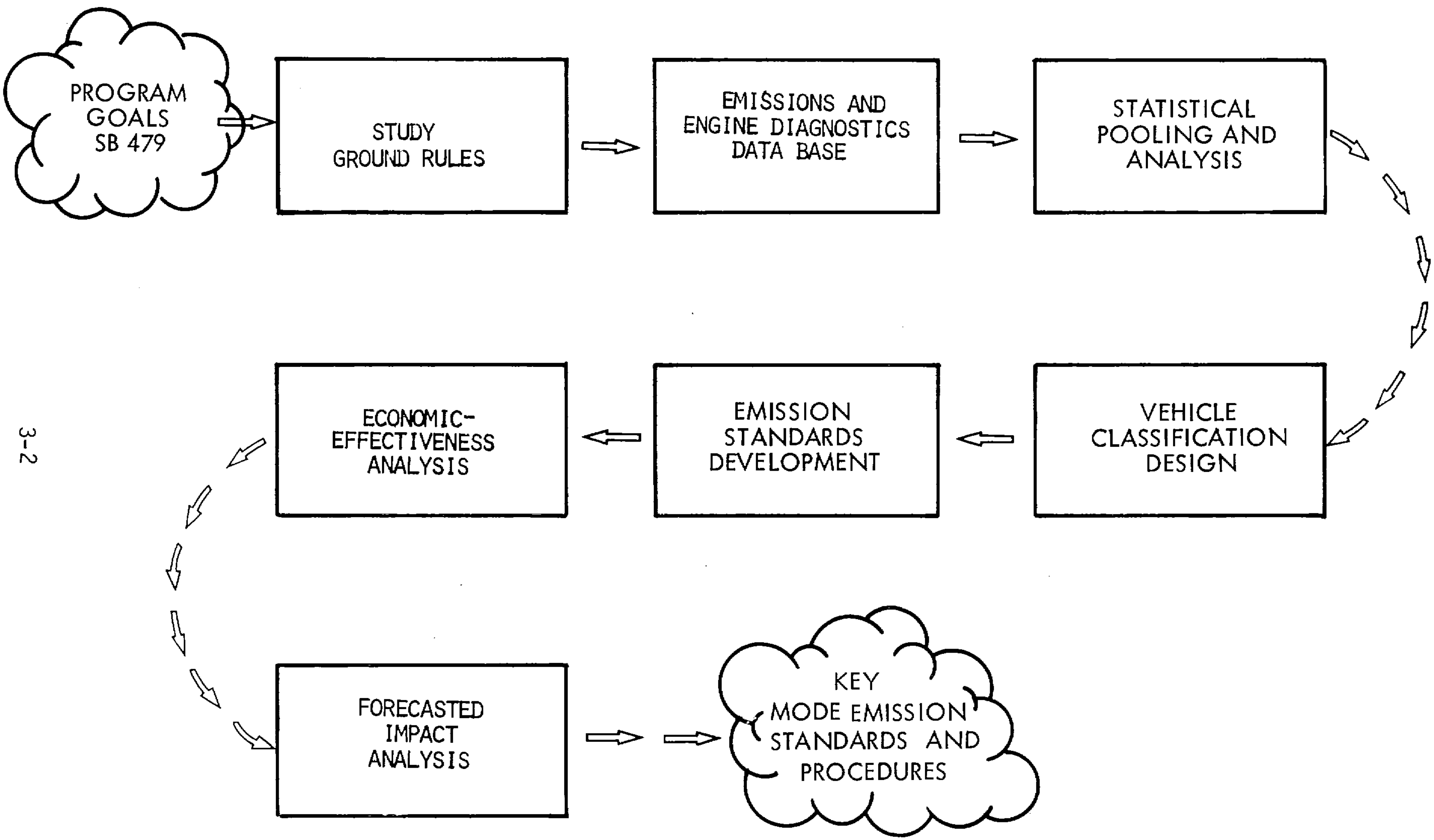

Figure 3-1. Methodological Overview

TABLE 3-1

ENGINE AND EMISSION DATA BASE

	Source	Sample Size	Engine Diagnostics	CVS	Idle	Key Mode Low Cruise	High Cruise	Before/After Tuning	Vehicle Characteristics
1.	TRW CAPE-13 (1972)	450	A/F RPM Timing Misfire AP Heat Riser Valve NOx Control PCV Choke AC	HC CO NOx	HC CO NOx	HC CO NOx	HC CO NOx	Pre-Post Deterioration	65-72 Make Weight Cubic Displacement EM/AR
2.	ARB Surveil-lance	2,000	A/F AC	NONE	HC CO	NONE	NONE	Pre	65-74 Cubic displacement EM/AR
3.	ARB Advanced Vehicles	160	A/C	HC CO	NONE NOx(some)	NONE	NONE	Retrofit Deterioration	1966-1973 Make (some) No. cylinders(some) Cubic Displacement
4.	Northrop/Olson (1970)	1,500	AP A/F RPM	NONE NOx(some)	HC CO	HC CO	HC CO	Pre-Post	65-70 Make EM/AR Cubic displacement No. cylinders
5.	AAA	100	Timing A/F	NONE	NONE	NONE	NONE	Post	1972 Make Weight Cubic displacement No. cylinders
6.	EPA Pre-Controlled	100	A/F	HC CO NOx	HC CO	HC CO	HC CO	Pre-Post	Pre-control Make
7.	EPA Six Cities Los Angeles	175	A/F DWELL RPM Timing	HC CO NOx	HC CO NOx	NONE	NONE	Pre	65-71 Make Weight Cubic displacement No. cylinders

relevant characteristics of each data base. All of the listed sets were developed from vehicles operating within the South Coast Air Basin. Table 3-1 depicts the basic data required to systematically develop a set of loaded mode emission standards. As can be seen, there are numerous voids in this data matrix which tend to confound the problem of obtaining a representative sample set. An analysis of these data sets led to the following conclusions:

- For loaded mode emissions, only the TRW and Northrop/Olson samples had good statistical agreement. Idle HC and idle CO emissions from the ARB Data Base appeared consistently lower for the same sample period.

- The TRW Data Base provides the only pre/post maintenance CVS mass emission results. A comparison between the EPA Six City study and the TRW data for pre-maintained cars reveals statistically consistent results.

- TRW, Northrop/Olson and EPA engine diagnostic data on pre-maintained vehicles showed a consistent trend.

3.3 Vehicle Classification Matrix

Exhaust emission levels tend to vary as a function of vehicle age and engine characteristics. If the vehicle population consists of several different emission groups because of inherent design characteristics, then a uniform set of standards would be inappropriate. For example, pre-controlled four cylinder engines appear to have a significantly higher CO emission concentration at idle than either six or eight cylinder engines. Thus, in a classification design where four's were combined in with six's and eight's, they would bear a disproportionate amount of the costs. Therefore, it is desirable to develop a classification scheme which takes into account differences in vehicle emission behavior.

Basically, the question of population homogeneity can be broken down into two parts. First, do any significant differences among vehicular emission concentrations exist, and second, if so, where do they lie. A statistical technique, known as analysis of variance, was used to answer the first part of the question while the second part was answered using multiple comparison methods.

Analysis of Classification Alternatives

Ideally, all factors of engine and vehicle design which might influence key mode emission concentrations such as carburetion, ignition, and projected frontal area should be analyzed for statistically significant effects. Operationally, however, this was not practical. Therefore, the investigation was limited to those factors which could be readily assessed at a vehicle inspection station either from the vehicle's registration card or visual appearance. Furthermore, it was recognized that from an engineering standpoint, certain types of pollution control equipment would also have to be considered.

Thus, on the basis of the above criteria, five design factors were selected for detailed study. They were age, weight, displacement, number of cylinders, and type of control. The last factor was considered only on vehicles of vintages 1966 through 1970, and consisted of classifying the exhaust control device as either air (air pump) or non-air (usually engine modification). Of these five factors adequate data existed to explore their effects on emission concentrations except for gross weight. Therefore, it was necessary to drop weight from the final set of design factors.

Classification Design

As stated before, the actual vehicle classification matrix used in establishing the emission standards was developed from the analysis of variance results using the pooled data base. However, two additional considerations were also taken into account. First, from both an operational and technical standpoint, it was decided that the formulation of separate classification schemes for HC and CO was not desirable. Second, for 1966-1970 vehicles a distinction was made between air and non-air vehicles at idle. This was found to be more efficient than differentiating between engine displacement primarily because very few four cylinder 1966-1970 vehicles were equipped with air pumps.

Based on these considerations the vehicle classification design finally selected was as follows:

<u>Idle</u>

Pre-1966	-	(4 cylinders), (6 and 8 cylinders)
1966-1970	-	(air), (non-air)
Post-1970	-	(4 cylinders), (6 and 8 cylinders)

<u>Low and High Cruise</u>

Pre-1966	-	(4 cylinders), (6 and 8 cylinders)
1966-1970	-	(4 cylinders), (6 and 8 cylinders)
Post-1970	-	(4 cylinders), (6 and 8 cylinders)*

It should also be noted that twelve cylinder engines are implicitly considered to be grouped with the eights.

3.4 Emission Standards Development

The design of effective emission standards required the consideration of a number of complex factors. The highlights of the basic approach used in the study are presented below.

- Emission standards were developed based on a consideration of the interaction between individual modes and emission species.

* The analysis also indicated the need to provide specific standards for 1971-1974 vehicles equipped with air pumps. Unfortunately, the data base did not contain information on air pump equipped vehicles (specifically 1973-1974) and, therefore, engineering estimates were required.

- Optimal rejection levels were based on cost-effectiveness considerations within individual engine classifications. Emission standards were designed to reject nearly equal levels across defined engine classifications.

- No special consideration was given to any particular mode. All emission standards were determined by cost-effective analysis.

- Emission standards were designed with an emphasis on HC reductions (specific emission weighting factors are: HC - 0.6, CO - 0.1, NOx - 0.3).

- Vehicle loaded modes were rank ordered as a function of weighted emission reductions.

- Loaded mode standards were developed, for a given rejection level, based on maximum weighted CVS emission reductions.

- The emission reduction effectiveness results were developed from vehicles receiving a complete tune-up.

- Vehicles failing a single mode (e.g., idle) were subject to the repair of all detectable maladjustments and malfunctions.

- Unique pass/fail criteria were established for each age and engine classification.

- Thirty six different emission standards were required to optimally characterize the vehicle population (3 modes x 2 emissions x 3 age groups x 2 engine classes).*

An important feature of emission standards determination is the effect of interactions between the modes and emissions, i.e., a vehicle may be rejected for multiple standard violations. Setting a rejection level of 20 percent for each mode and emission would result in a total rejection factor substantially greater than 20 percent.

3.5 Cost-Effectiveness and Predictive Analysis

The design of effective emission standards requires consideration of their impact on both the short and long term performance of the program. This study utilized a cost-effectiveness approach in establish-

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* In addition, separate standards were specified for air pump and non-air pump equipped vehicles and for NOx emissions

ing optimal emission standards.* Here, tradeoffs were performed between the effectiveness and associated costs for various levels of vehicle rejection. This type of analysis provides a short term view on the overall performance of the program, since it is based on a static data base. The impact of the defined standards on long term performance was evaluated using TRW's Economic-Effectiveness Model. This combination of cost-effective and predictive analysis provided a comprehensive approach to the problem of standards design.

Cost-Effective Analysis

The specific method selected for comparing the cost effectiveness of alternative rejection rates is given below:

EC = WER/TPC

where:

EC = Effectiveness-cost ratio

WER - Weighted emission reduction for HC, CO and NOx

TPC = Total program cost including both capital and operating.

The idea is to find a rejection level (R) for each vehicle classification element such that the effectiveness cost ratio is a maximum. Figure 3-2 illustrates the classical tradeoff between emission reduction effectiveness and costs as a function of vehicular rejection. As can be seen, effectiveness increases proportionally to rejection rate until reaching a maximum. Beyond that point effectiveness drops off as rejection rate continues to increase.

* A cost-effective approach in lieu of a cost-benefit approach is necessary because of the general inability to characterize the resultant benefits of the program in dollar terms. This is especially the case in analyzing one element of an environmental control program (e.g., inspection/maintenance). While "technically less correct" this approach can yield systematic and meaningful results.

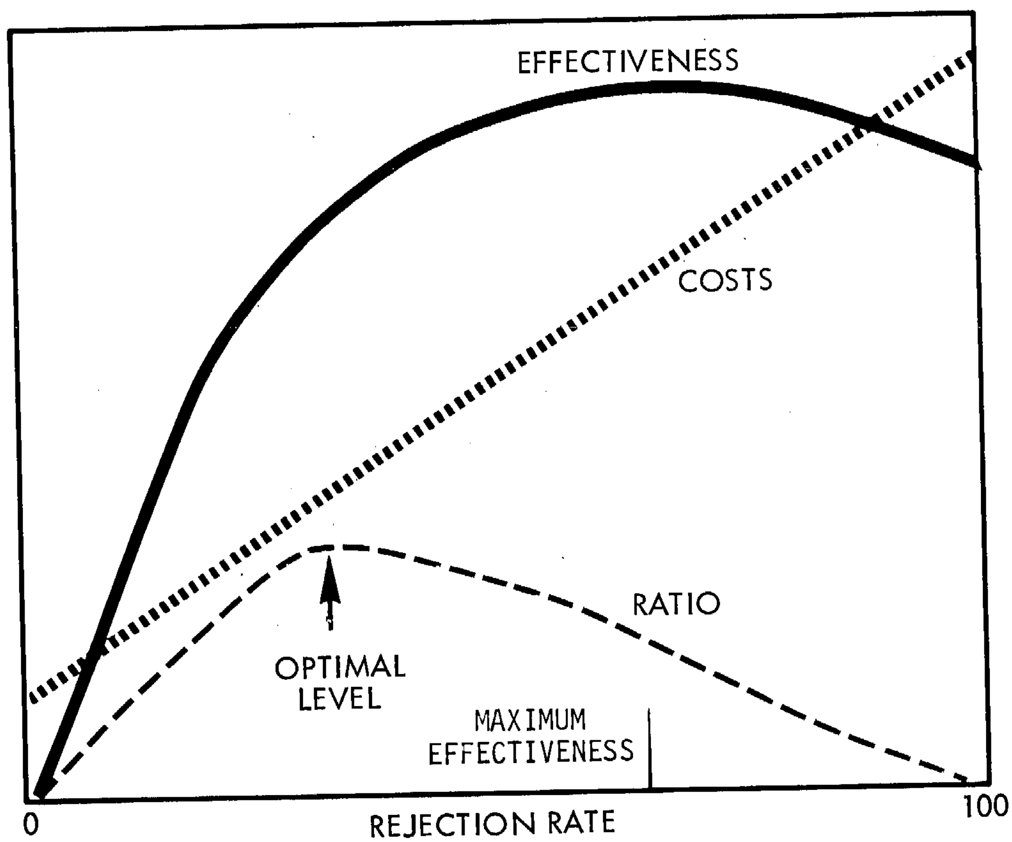

Figure 3-2. Program Effectiveness and Cost Profiles

Predictive Analysis

The primary purpose of TRW's Economic Effectiveness Model is to serve as a research and design tool for assessing the long term implications of various inspection/maintenance alternatives. The development of the model required a detailed specification of the numerous relationships governing the inspection/maintenance process. Figure 3-3 outlines the essential features of the present model.

The model "bookkeeps" the emission levels for each type and combines them to form aggregate levels for the entire population. The composition of the aggregate fleet changes over time as new cars are introduced into the population and older cars leave. Consequently, the importance of the post-1970 vehicles grows with time. This dynamic state of the vehicle population underscores the need for long term predictive analysis in arriving at effective emission standards.

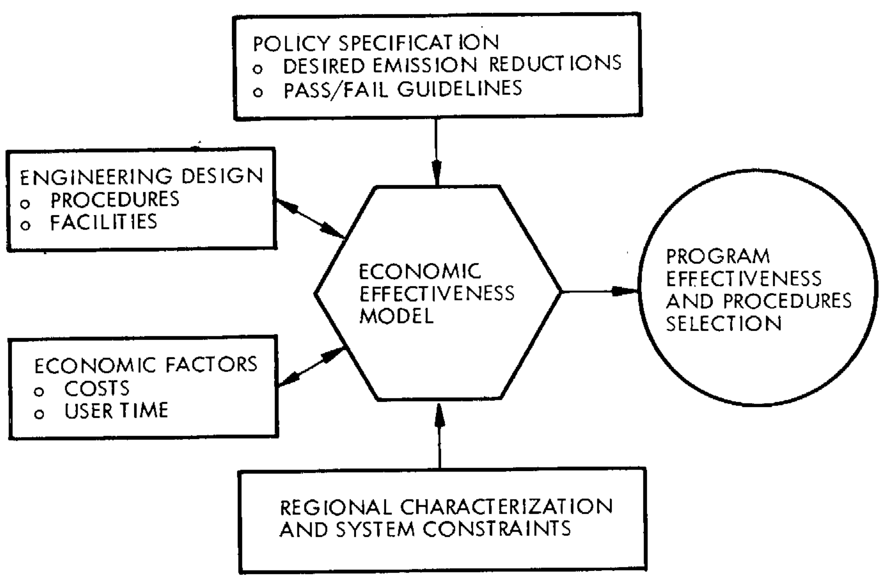

Figure 3-3. Schematic of Economic Effectiveness Model

4.0 KEY MODE EMISSION STANDARDS

This section presents the results from the study. First, the developed emission standards are presented and reviewed. Next, the cost-effectiveness analysis techniques are discussed and graphically illustrated. The effect of the optimal emission criteria on each vehicle group is then considered. The CAPE-13 data base was augmented by the Northrop/Olson and ARB data sets for this purpose. A detailed evaluation is given on establishing NOx emission standards and procedures for 1971-1974 vehicles. This analysis in turn leads to the development of emission standard procedures for post-1974 vehicles. The developed emission standards are re-examined in light of establishing potential re-test criteria. The impact of the defined standards on program performance is then forecast over a five year interval. Finally, a cost analysis is presented on the various elements of the program.

4.1 Emission Inspection Criteria

The developed loaded mode emission standards reflect the total set of interactions between the various operating modes and emission signatures. Table 4-1 summarizes the recommended emission standards for each of the vehicle classification elements. These standards are designed to fail approximately 30 percent of the vehicle population. As can be seen from the table, different standards have been established at idle for those 1966-1970 vehicles with and without an air pump. For the cruise modes, however, no distinction is made between the two types of control since they were shown not to be statistically different. These standards apply to both four and six or eight cylinder vehicles.

TABLE 4-2

VEHICLE REJECTION FACTORS BY POPULATION CLASSIFICATION

As Received

Year \ CYL	4	6	8
Pre 1966	40%	32%	
1966-1970	46%	29%	
1971-1974	33%	26%	

Post-tune

Year \ CYL	4	6	8
Pre 1966	0%	5%	
1966-1970	15%	10%	
1971-1974	8%	1%	

Post-Deterioration

Year \ CYL	4	6	8
Pre 1966	20%	20%	
1966-1970	50%	35%	
1971-1974	35%	25%	

population tend to return to their "as received" state after one year of deterioration. The observation should be tempered with the fact that the deterioration data was developed under "laboratory conditions" and, therefore, does not totally reflect the dynamic state of the vehicle population (i.e., vehicle attrition and owner tampering).

4.2 Cost-Effectiveness Analysis

The techniques outlined in Section 3.5 were used in conjunction with basic emissions and cost data to determine the optimal level of vehicle rejection for a given set of emission standards. Figure 4-1 illustrates effectiveness and cost-effectiveness results for 1966 to 1970 vintage cars. Here, the "optimal" rejection level, based on cost-effective considerations, appears to be 30 percent while maximum emission reduction effectiveness occurs at over 60 percent. The cases for pre-1966 and 1971-1974 vehicles showed similar trends.

4.3 NOx Standards and Procedures

A basic objective in establishing NOx emission standards for post-1970 vehicles is to ascertain the operability of the NOx control systems. Since current emission signature technology can not effectively diagnose NOx control failures, another approach is required. The approach selected involves the development of a NOx screening standard. Here, a simple loaded mode test is used to identify potential malfunctioning systems for subsequent direct diagnostic evaluation. These concepts are illustrated in Figure 4-2.

Shown are emission distributions for vehicles with operating and failed NOx control systems. Typically the emission distribution for

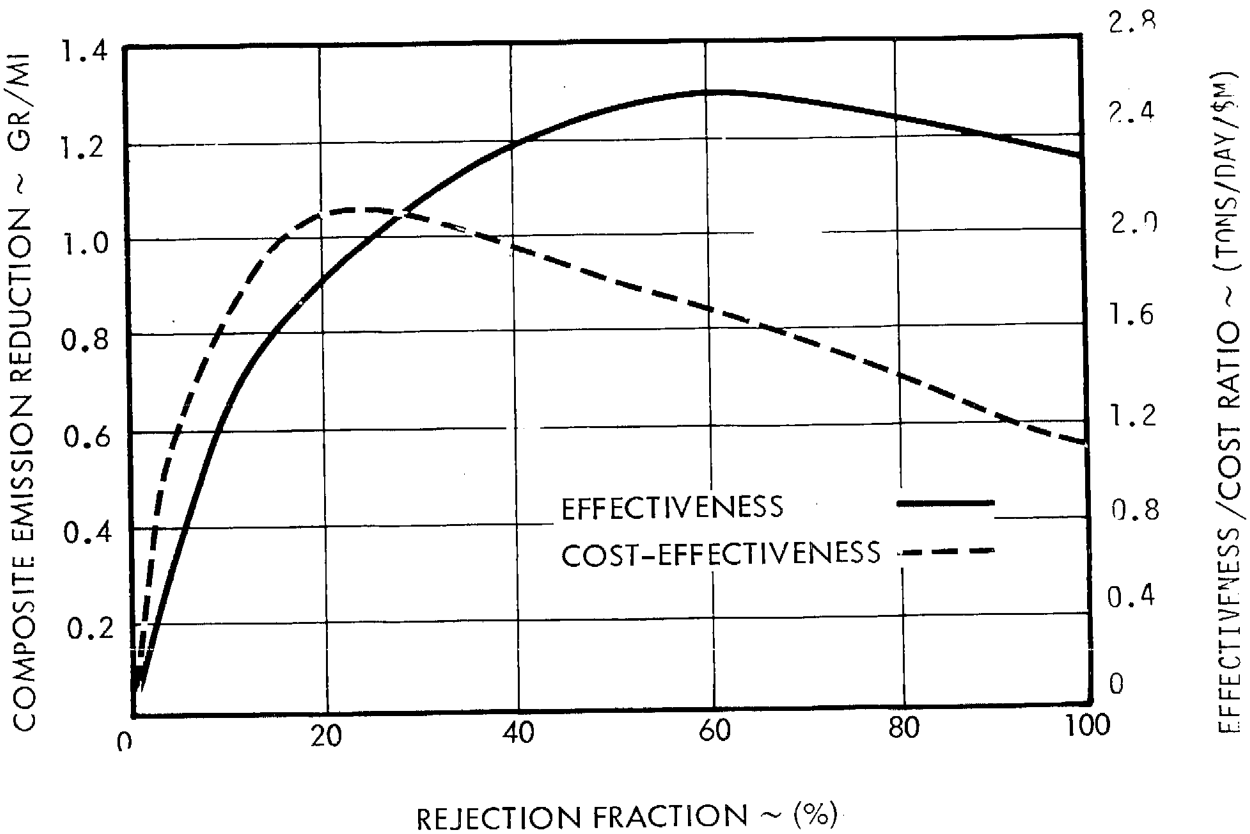

Figure 4-1. Program Performance for 1966-1970 Vehicles

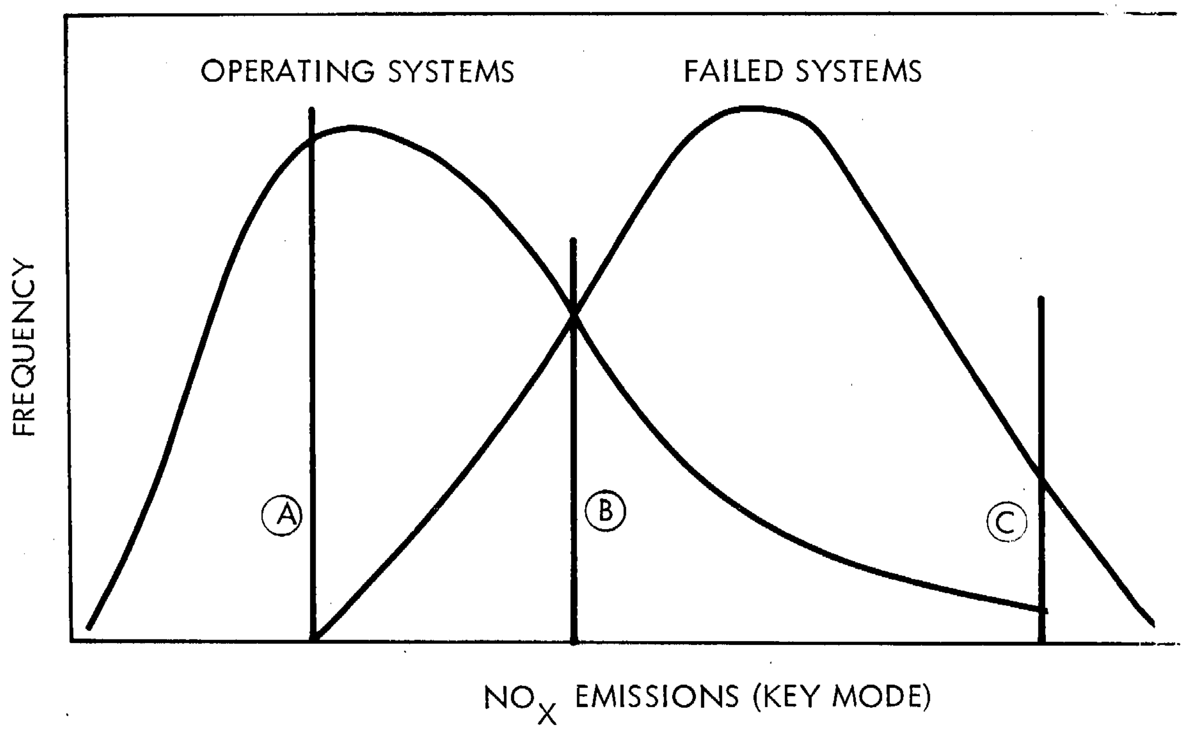

Figure 4-2. Schematic of Ideal NOx Emission Test

vehicles with operating NOx systems tends to be lower than for failed systems. Using these differences, a specific NOx standard can be established based on one of three criteria: minimize errors of omission (A), minimize total errors (B), and minimize errors of commission (C). Those vehicles failing the test could then be taken out of the production inspection lane for detailed diagnostic analysis. This screening procedure could also be applied to other advanced emission control systems (e.g., catalyst).

4.4 Inspection Standards Development for Post-1974 Vehicles

The standards developed in this report have been designed for the current in-use fleet (i.e., through 1974). Since the proposed inspection program will continue for an indefinite period, it becomes important to identify procedures for establishing standards for post-

1974 vehicles. Because future motor vehicles will have relatively complex emission systems, it is difficult to extrapolate meaningful standards from historical trends. Furthermore, the variability in emission control systems by vehicle type, at this time, precludes the development of a systematic classification matrix for these advanced vehicles. In fact, it appears that some form of engine diagnostic approach may be necessary to effectively evaluate the performance characteristics of these systems. As a result of these considerations the following procedures are recommended with respect to establishing initial inspection standards for post-1974 vehicles.

HC and CO Standards. Use the standards and partitioning scheme developed in this report for HC and CO emissions for 1971 through 1974 model year vehicles, until standards specific to 1975 model year vehicles can be developed.

NOx Standards. Use the standards and partitioning scheme developed in this report for NOx emissions for 1971 through 1974 model year vehicles, until validated standards for 1971 through 1974 and 1975 model year vehicles can be developed.

Data Gathering. Perform additional loaded-mode tests on approximately 200 1975 model vehicles as they are admitted for mandatory inspection, measuring emissions of HC, CO and NOx and using control device manipulations to correlate malfunctions with measured emission levels.

The application of these interim standards for new vehicles will not cause significant perturbations on overall vehicle rejection rates, since they will be in effect only a short time, and since new vehicles during this time will account for only a few percent of the total vehicle population. The same procedure should be followed during the beginning of each succeeding model year.

4.5 Emission Re-Test Criteria

The concept of establishing re-test emission standards which are more stringent than the initial inspection standards is potentially applicable to the South Coast Air Basin program. Vehicles failed during the initial inspection are sent to repair facilities for adjustment. Conceptually speaking, these adjustments would be made to meet a re-test standard which is lower numerically than the original inspection standard. After adjustment, the vehicle is re-tested and if it fails, it is returned to the repair facility for readjustment. The concept is most appropriate for dealing with idle CO emissions, for the following reasons:

- Idle CO is both an emission and an engine parameter; it is solely dependent on carburetor adjustment. Other emissions are generally related to engine or equipment malfunctions.
- Idle CO emissions can usually (barring carburetor malfunctions) be adjusted continuously over a range of values, and it is, therefore, relatively easy for the repair mechanic to set idle CO emissions for meeting a particular standard. This is not true in general for other pollutant species.
- Very few repair agencies have facilities for checking emissions under load, while many can check and adjust idle CO.

There are both advantages and disadvantages with using this concept rather than simply using the same standard for both initial inspection and re-test. These are as follows:

<u>Advantages</u>

- The stringent re-test standard will reduce aggregate emissions from the vehicle population in the South Coast Air Basin.

- It will help insure that the repair facility does indeed adjust each failed vehicle for low emissions.

- It will serve as encouragement to the vehicle owner to obtain maintenance before the initial test or prior to the re-test inspection.

Disadvantages

- Stringent re-test standards may lead to public relations problems. (That is, it may seem unfair to some owners that one set of standards is more stringent than another for the same pollutant.)

- It may increase the likelihood of a "ping-pong" effect, in that some cars may have to go through several cycles of maintenance and re-test before passing a more stringent re-test standard.

- It may result in higher costs for repair, as a result of the possible ping-pong effect and the additional requirements for idle CO.

Based on these factors, it is recommended that consideration should be given to establishing repair procedures that are designed to adjust idle CO to manufacturers' specification instead of only to the emission standards. This approach would permit better program control and would insure more effective results.

4.6 Forecasted Impact of Emission Standards

TRW's Economic Effectiveness Computer Model, along with the experimental emission data base, was used to assess the long term impact of the developed standards on program performance. Forecasts were prepared for the 1974-1978 period. The end point coincides with the limits of reasonable certainty concerning the distribution of power plants to be manufactured over the next few years.

The specific case simulated over this time frame consisted of the following elements:

- Measurement of idle , low cruise and high cruise HC, CO, and NOx for the entire South Coast Air Basin vehicle population.
- Identification of specific engine maladjustments and malfunctions through an interpretation of modal signatures using established key mode emissions.
- Repair of vehicles with identified maladjustments and malfunctions. The particular engine parameters included: idle air/fuel ratio, idle rpm, timing, misfire, PCV valve, air cleaner, air pump, NOx control and choke system.

This process (measurement, identification and repair) was simulated on an annual basis over the five year period. The model also considers the impact of engine deterioration, owner tampering and unreliable repair on overall program performance. Thus, it is designed to provide "real" world estimates on the expected cost-effectiveness of the proposed emission standards.

Some typical quantitative results obtained from the simulations are presented in Figures 4-3 and 4-4. Figure 4-3 shows a set of forecasted emission time curves for the HC (Panel A), CO (Panel B) and NOx (Panel C) through 1978. Two opposite effects are shaping these profiles - emission increases due to engine deterioration and emission decreases due to corrective maintenance and the introduction of new vehicles with lower emission levels. A baseline curve (assuming no inspection/maintenance program) is also shown for comparative purposes. These results clearly indicate that the key mode inspection program can help in reducing emission levels from the vehicle population.

Figure 4-4 presents a forecast of vehicle rejection fraction by age category assuming the use of the same standards over the simulated interval. The standards developed for 1971-1974 cars also were applied

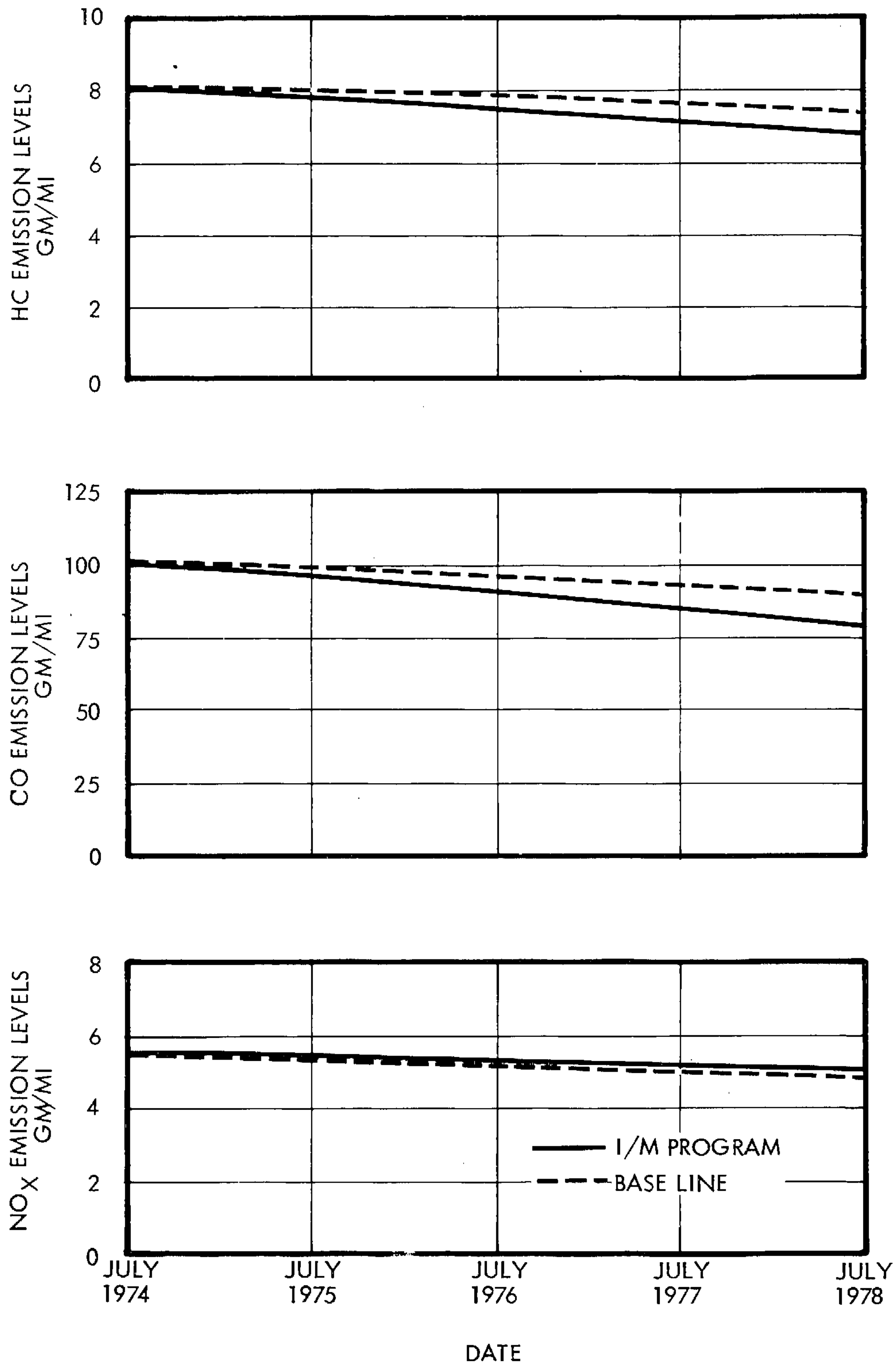

Figure 4-3. Forecasted Emission Levels by Vehicle Class Through 1978

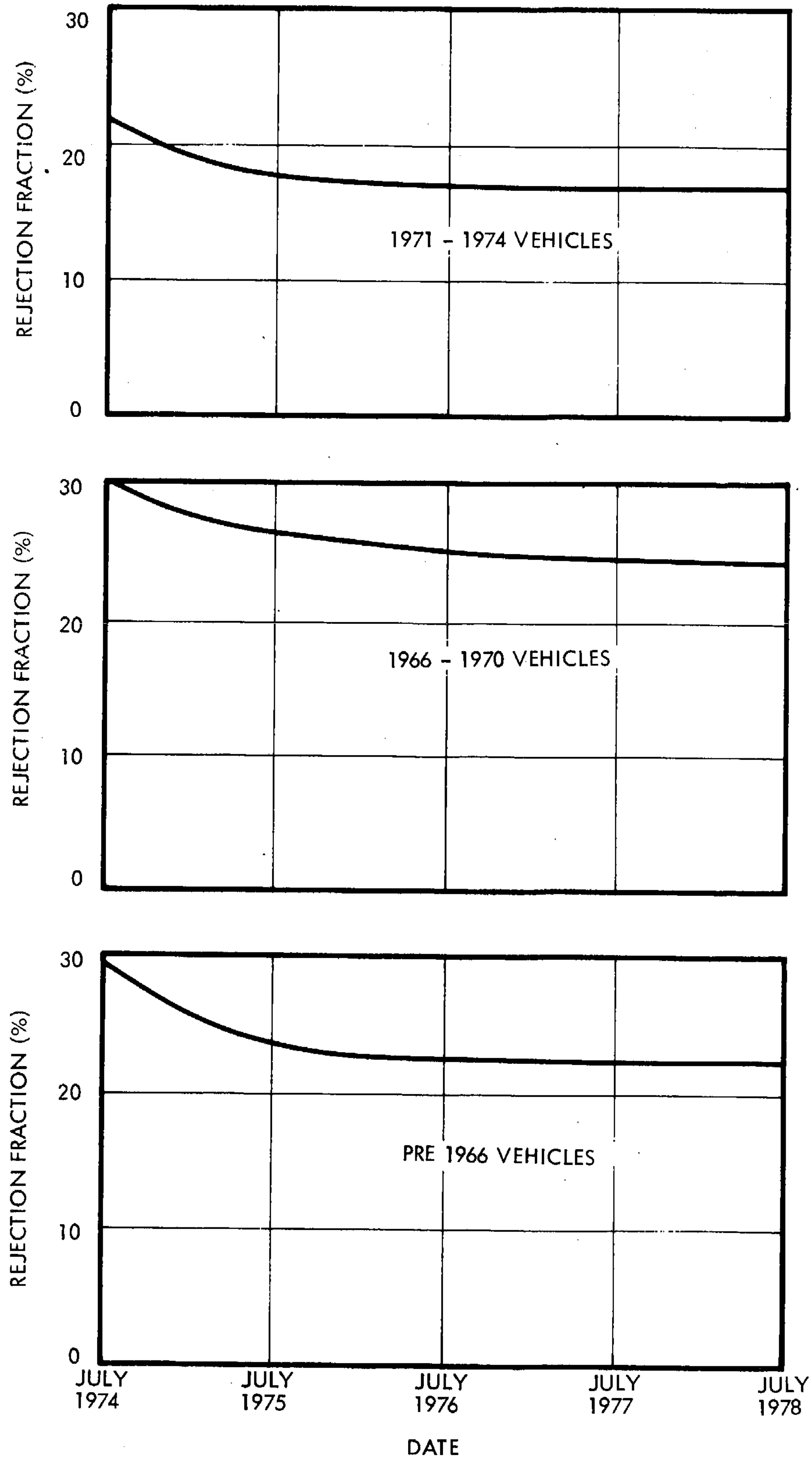

Figure 4-4. Forecasted Rejection Levels by Vehicle Class Through 1978

to the post-1974 vehicles.* The key observation obtained from this graph is the gradual reduction and the stablization of the rejection fraction as a function of time. These trends can be attributed to the ability of the inspection program to identify and maintain malfunctioning vehicles operating within the vehicle population

These forecasts show that it might be necessary to upgrade the emission standards periodically in order to achieve a consistent level of emission reduction from the vehicle population. A revised set of emission standards can be developed using the methodology outlined in this report.

4.7 Program Cost Analysis

The following discussion outlines the cost analysis procedures used to support the cost-effectiveness calculations reported in Section 4.2. The analysis also evaluates the potential impact of social costs on optimal rejection rates.

The explicit costs (i.e., the capital, operational and maintenance costs) of an inspection program can be divided into two components, namely, fixed costs and variable costs. Fixed costs include the cost of inspection facilities, equipment, land, and inspection operating expenses. They are constant for a given system configuration and typically are only indirectly a function of rejection level. Variable costs, on the other hand, are directly dependent on rejection rate, consisting mainly of the costs of the parts and labor necessary to repair

* The model presently assumes that emission levels for post-1974 vehicles can be characterized in terms of 1971-1974 vehicles (lack of data precludes direct characterization). For relative comparisons, the impact of this assumption will be slight.

vehicles which have failed inspection. Table 4-3 provides an estimate of inspection costs for the proposed program. On a region wide basis these costs were estimated to total roughly twenty million dollars or four dollars per vehicle.

The estimated sum of the inspection and maintenance program costs for selected rejection rates is given in Figure 4-5. These estimates include the costs of repair for those vehicles failing the inspection. For a rejection rate of 30 percent the average annual total program cost appears to be nearly $70 million. In general, these cost estimates reflect a linear growth rate as a function of rejection fraction.

Finally, the impact of implicit or social costs on program cost-effectiveness was estimated by determining the opportunity cost of time spent by the vehicle owner in the inspection/maintenance process. Since it is anticipated that the inspection program will be conducted during working hours, the opportunity cost of the time involved is the value of foregoing wages. This value was placed at $2.00 per hour, the minimum wage in California. A comparison of the cost-effective results with and without the addition of social costs did not reveal a significant shift in the optimal rejection rate. Only in one case (i.e., post-1970 vehicles) did a modest shift in optimal rejection level occur. Thus, it appears that the rejection fractions selected on the basis of program costs are somewhat insensitive to the addition of social cost at the defined rate (i.e., $2.00/hr). It should be noted, however, that the overall cost-effective ratio becomes smaller with the addition of social costs. This could have an impact on the relative attractiveness of inspection/maintenance vis-a-vis other control alternatives (e.g., emission retrofit devices).

TABLE 4-3

SUMMARY OF INSPECTION COST ESTIMATES

<u>INVESTMENTS</u>	
Land Acquisition (50 stations x 50K/station)*	$ 2,500,000
Facility Design and Construction (50 stations x 75K/station)	$ 3,750,000
Equipment (50 stations x 70K/station)	$ 3,500,000
Training and Certification	$ 250,000
TOTAL INVESTMENT	$10,000,000**
<u>OPERATIONS AND MAINTENANCE</u>	
Personnel Cost (840 employs x 10K/employ)	$ 8,400,000
Training	$ 100,000
Equipment/Facility Maintenance, Insurance and Misc.	$ 125,000
Computer Operations (@ 25¢ per test)	$ 1,375,000
TOTAL OPERATIONS AND MAINTENANCE	$10,000,000
<u>ANNUAL OPERATING COSTS</u>	
Total	$20,000,000
Total Per Registered Vehicle (@5.0 million)	$4.00/car

* Assumes 4 lanes per station at 25,000 cars per lane/year.

** Due to the uncertain nature of the program financing, capitalization costs were assummed to be incurred over a period of one year.

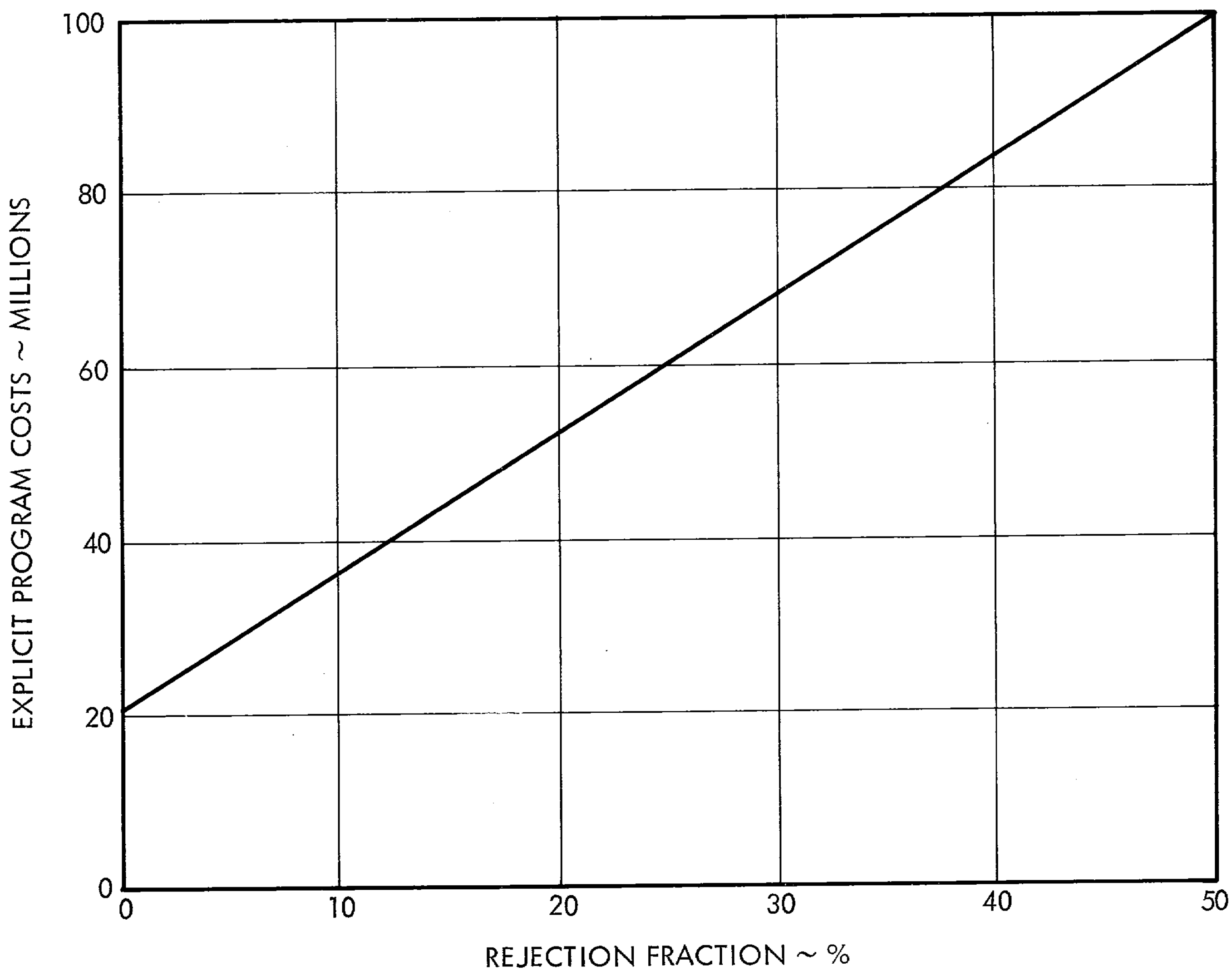

Figure 4-5. Program Costs as a Function of Vehicle Rejection Fraction